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**FLUORINATED ALKENE REFRIGERANT COMPOSITIONS**

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## **FLUORINATED ALKENE REFRIGERANT COMPOSITIONS**

### **RELATED APPLICATIONS**

The present application is related to and claims the priority benefit of U.S. Provisional Application Nos. 60/421,263, and 60/421,435, each of which was filed on Oct. 25, 2002 and each of which is incorporated herein by reference. The present application is also related to and incorporates by reference each of the following concurrently filed U.S. Patent Applications: Attorney Docket Number H0004412 (26,269) entitled "COMPOSITIONS CONTAINING FLUORINE SUBSTITUTED OLEFINS," by Singh et al. and Attorney Docket Number H0003789 (26,267) entitled "PROCESS FOR PRODUCING FLUOROPROPENES," by Tung et al.

### **FIELD OF THE INVENTION**

The present invention relates to compositions used as refrigeration fluids in compression refrigeration, air-conditioning and heat pump systems.

### **BACKGROUND OF THE INVENTION**

The use of chlorine-containing refrigerants, such as chlorofluorocarbons (CFC's), hydrochlorofluorocarbons (HCF's) and the like, as refrigerants in air-conditioning and refrigeration systems has become disfavored because of the ozone-depleting properties associated with such compounds. As a result, it has become desirable to retrofit chlorine-containing refrigeration systems by replacing chlorine-containing refrigerants with non-chlorine-containing refrigerant compounds that will not deplete the ozone layer, such as hydrofluorocarbons (HFC's).

In order for any of the replacement materials to be useful in connection with refrigeration compositions, the materials must be compatible with the lubricant utilized in the compressor. Unfortunately, many non-chlorine-containing refrigeration fluids, including HFC's, are relatively insoluble and/or immiscible in the types of

lubricants used traditionally with CFC's and HFC's, including, for example, mineral oils, alkylbenzenes or poly(alpha-olefins). In order for a refrigeration fluid-lubricant combination to work efficiently within a compression refrigeration, air-conditioning or heat pump system, the lubricant must be sufficiently soluble in the refrigeration liquid over a wide range of operating temperatures. Such solubility lowers the viscosity of the lubricant and allows it to flow more easily throughout the system. In the absence of such solubility, lubricants tend to become lodged in the coils of the compression refrigeration, air-conditioning or heat pump system evaporator, as well as other parts of the system, and thus reduce the system efficiency.

Polyalkylene glycol, esterified polyalkylene glycol, and polyol ester lubricating oils have been developed as miscible lubricants for HFC refrigeration liquids. Polyalkylene glycol refrigeration lubricants are disclosed by U.S. Patent No. 4,755,316; 4,971,712, and 4, 975, 212. Polyalkylene glycol esters are disclosed by U.S. Patent No. 5,008,028. The polyalkylene glycol and polyalkylene glycol ester lubricating oils are disclosed as being miscible in fluoroalkanes containing one or two carbon atoms and no double bonds.

Consequently fluorocarbon-based fluids have found widespread use in industry for refrigeration system applications, including air-conditioning systems and heat pump applications as well, all of which involve compression refrigeration. Compression refrigeration generally involves changing the refrigerant from the liquid to the vapor phase through heat adsorption at a lower pressure and then from the vapor to the liquid phase through heat removal at an elevated pressure.

While the primary purpose of refrigeration is to remove energy at low temperature, the primary purpose of a heat pump is to add energy at higher temperature. Heat pumps are considered reverse cycle systems because for heating, the operation of the condenser is interchanged with that of the refrigeration evaporator.

The art is continually seeking new fluorocarbon and hydrofluorocarbon-based pure fluids that offer alternatives for refrigeration and heat pump applications. Applicants have come to appreciate that fluoro-olefin-based materials (fluoroalkenes) are of particular interest because they have characteristics that make them environmentally safer substitutes for the presently used fluoroalkanes (HFC's), that  
5 despite being safe for the ozone layer are suspected of causing global warming.

Applicant has also come to recognize that refrigeration composition substitutes for HFC's in many cases preferably possess certain performance  
10 properties to be considered acceptable substitutes, including acceptable refrigeration characteristics, chemical stability, low toxicity, non-flammability, lubricant compatibility and efficiency in use. The latter characteristic is important in many refrigeration systems, air-conditioning systems and heat pump applications, especially when a loss in refrigeration thermodynamic performance or energy  
15 efficiency may have secondary environmental impacts through increased fossil fuel usage arising from an increased demand for electrical energy. Furthermore, it would be advantageous for HFC refrigeration composition substitutes to not require major engineering changes to conventional vapor compression technology and lubricant systems currently used with HFC refrigeration liquids.

20 Flammability is another important property for many applications. That is, it is considered either important or essential in many applications, including particularly in heat transfer applications, to use compositions which are non-flammable. Thus, it is frequently beneficial to use in such compositions compounds which are  
25 nonflammable. As used herein, the term "nonflammable" refers to compounds or compositions which are determined to be nonflammable in accordance with ASTM standard E-681, dated 2002, which is incorporated herein by reference. Unfortunately, many HFC's which might otherwise be desirable for used in refrigerant compositions are not nonflammable. For example, the fluoroalkane

difluoroethane (HFC-152a) and the fluoroalkene 1,1,1-trifluoropropene (HFO-1243zf) are each flammable and therefore not viable for use in many applications.

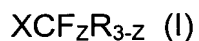
Higher fluoroalkenes, that is fluorine-substituted alkenes having at least five carbon atoms, have been suggested for use as refrigerants. Smutny, U.S. Patent No. 4,788,352 is directed to production of fluorinated C<sub>5</sub> to C<sub>8</sub> compounds having at least some degree of unsaturation. The Smutny patent identifies such higher olefins as being known to have utility as refrigerants, pesticides, dielectric fluids, heat transfer fluids, solvents, and intermediates in various chemical reactions.

While the fluorinated olefins described in Smutny may have some level of effectiveness in heat transfer applications, it is believed that such compounds may also have certain disadvantages. For example, some of these compounds may tend to attack substrates, particularly general-purpose plastics such as acrylic resins and ABS resins. Furthermore, the higher olefinic compounds described in Smutny may also be undesirable in certain applications because of the potential level of toxicity of such compounds which may arise as a result of pesticide activity noted in Smutny. Also, such compounds may have a boiling point which is too high to make them useful as a refrigerant in certain applications.

Applicant have thus come to appreciate a need for compositions, and particularly fluid transfer compositions that are potentially useful in numerous applications, including vapor compression heating and cooling systems and methods, while avoiding one or more of the disadvantages noted above. Moreover, applicant has also recognized that in many applications there remains a need for fluorocarbon and hydrofluorocarbon-based refrigeration liquids that are environmentally safer than HFC's, possess similar or better characteristics with respect to at least certain refrigerant thermodynamic performance properties, and are compatible with existing lubricant systems.

## SUMMARY

Applicants have found that the above-noted needs, and other needs, can be  
5 satisfied by compositions comprising one or more C3 or C4 fluoroalkenes, preferably  
compounds having Formula I as follows:



where X is a C<sub>2</sub> or a C<sub>3</sub> unsaturated, substituted or unsubstituted, alkyl radical, R is  
10 independently Cl, Br, I or H, and z is 1 to 3. The present compositions also  
preferably include one or more lubricants in combination with one or more of the  
compounds of the present invention.

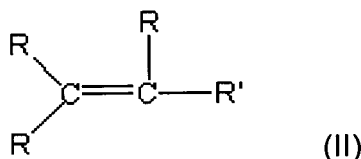
The present invention provides also methods and systems which utilize the  
15 heat transfer compositions of the present invention.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

### THE COMPOSITIONS

5 The present invention is directed to compositions comprising at least one fluoroalkene containing from 3 to 4 carbon atoms and at least one carbon-carbon double bond. The fluoroalkene compounds of the present invention are sometimes referred to herein for the purpose of convenience as hydrofluoro-olefins or "HFOs." Although it is contemplated that the HFOs of the present invention may contain two  
10 carbon - carbon double bonds, such compounds at the present time are not considered to be preferred.

As mentioned above, the present compositions comprise one or compounds in accordance with Formula I. In preferred embodiments, the compositions include  
15 compounds of Formula II below:



wherein each R is independently Cl, F, Br, I or H; R' is (CR<sub>2</sub>)<sub>n</sub>Y; Y is CRF<sub>2</sub> and n is 0 or 1. In highly preferred embodiments, Y is CF<sub>3</sub>, n is 0 and at least one of the  
20 remaining R's is F.

Applicant believes that, in general, the compounds of the above identified Formulas I and II are generally effective and exhibit utility in heat transfer applications in general and in compression refrigerant compositions in particular.  
25 However, it has been surprisingly and unexpectedly found that certain of the compounds having a structure in accordance with the formulas described above exhibit a highly desirable low level of toxicity compared to other of such compounds. As can be readily appreciated, this discovery is of potentially enormous advantage and benefit for the formulation of not only refrigerant compositions, but also any and  
30 all compositions which would otherwise contain relatively toxic compounds satisfying

the formulas described above. More particularly, it is believed that a relatively low toxicity level is associated with compounds of Formula II, preferably wherein Y is CF<sub>3</sub>, wherein at least one R on the unsaturated terminal carbon is H, and at least one of the remaining R's is F. It is believed also that all structural, geometric and stereoisomers of such compounds are effective and of beneficially low toxicity.

In highly preferred embodiments, especially embodiments which comprise the low toxicity compounds described above, n is zero. Thus, in certain preferred embodiments the compositions of the present invention comprise one or more compounds selected from the group consisting of trifluorpropene (HFC -1243), tetrafluorpropenes (HFO-1234), pentafluorpropenes (HFO-1225) and combinations of these. The trans-1234 isomer has a boiling point of approximately -19° C and the cis isomer has a boiling point of approximately +9° C. The trans isomer is particularly useful as a refrigerant and as an aerosol propellant.

It is even more preferred that the compounds of the present invention are the tetrafluorpropene and pentafluorpropene compounds in which the unsaturated terminal carbon has not more than one F substituent, specifically: 1, 3, 3, 3-tetrafluorpropene (HFO-1234ze); 2, 3, 3, 3-tetrafluorpropene (HFO-1234yf); and 1,2,3,3,3-pentafluorpropene (HFO-1225ze), and any and all stereoisomers of each of these. It has been discovered that such compounds have a very acute low toxicity level, as measured by inhalation exposure to mice and rats. On the other hand, it has been found that a relatively high degree of toxicity may be associated with certain compounds adaptable for use with the present compositions, namely, those compounds which have more than one F on the terminal unsaturated carbon, or which do not have at least one H on the terminal unsaturated carbon. For example, it has been discovered that 1,1,3,3,3-pentafluorpropene (HFO-1225zc) exhibits an unacceptably high degree of toxicity, as measured by inhalation exposure to mice and rats.

The preferred compounds of the present invention, namely, HFO-1225 and HFO-1234 are known materials and are listed in Chemical Abstracts databases.



HFO-1225 is commercially available, for example from Syntex Chemical Co. Furthermore, methods are described generally in the patent literature for producing fluoroalkenes. For example the production of fluoropropenes such as  $\text{CF}_3\text{CH}=\text{CH}_2$  by catalytic vapor phase fluorination of various saturated and unsaturated halogen-  
5 containing  $\text{C}_3$  compounds is described in U.S. Patent. Nos. 2,889,379; 4,798,818 and 4,465,786, each of which is incorporated herein by reference. U.S. Patent No. 5,532,419, which is also incorporated herein by reference, discloses a vapor phase catalytic process for the preparation of fluoroalkene using a chloro- or bromo-halofluorocarbon and H. EP 974,571, also incorporated herein by reference,  
10 discloses the preparation of 1,1,1,3-tetrafluoro-propene by contacting 1,1,1,3,3-pentafluoropropane (HFC-245fa) in the vapor phase with a chromium-based catalyst at elevated temperature, or in the liquid phase with an alcoholic solution of KOH, NaOH,  $\text{Ca}(\text{OH})_2$  or  $\text{Mg}(\text{OH})_2$ . In addition, methods for producing compounds in accordance with the present invention are described generally in connection with  
15 concurrently filed United States Patent Application entitled "Process for Producing Fluoropropenes" bearing attorney docket number (H0003789 (26,267USA)), which is also incorporated herein by reference.

The present compositions are believed to possess properties that are  
20 advantageous for a number of important reasons. For example, applicants believe, based at least in part on mathematical modeling, that the fluoroolefins of the present invention will not have a substantial negative affect on atmospheric chemistry, being negligible contributors to ozone depletion in comparison to some other halogenated species. The preferred compositions of the present invention thus have the  
25 advantage of not contributing substantially to ozone depletion. The preferred compositions also do not contribute substantially to global warming compared to many of the hydrofluoroalkanes presently in use.

Although it is contemplated that the compositions of the present invention may  
30 include the compounds of the present invention in widely ranging amounts, it is generally preferred that refrigerant compositions of the present invention comprise compound(s) in accordance with Formula I, and even more preferably Formula II, in

an amount that is at least about 50% by weight, and even more preferably at least about 70 % by weight, of the composition. For preferred compositions for use as blowing agents in accordance with the present invention, compound(s) in accordance with Formula I, and even more preferably Formula II, are present in an amount that is at least about 5 % by weight, and even more preferably at least about 15 % by weight, of the composition.

The compositions of the present invention may include other components for the purpose of enhancing or providing certain functionality to the composition, or in some cases to reduce the cost of the composition. For example, refrigerant compositions according to the present invention, especially those used in vapor compression systems, include a lubricant, generally in amounts of from about 30 to about 50 percent by weight of the composition. Furthermore, the present compositions may also include a compatibilizer, such as propane, for the purpose of aiding compatibility and/or solubility of the lubricant. Such compatibilizers, including propane, butanes and pentanes, are preferably present in amounts of from about 0.5 to about 5 percent by weight of the composition. Combinations of surfactants and solubilizing agents may also be added to the present compositions to aid oil solubility, as disclosed by U.S. Patent No. 6,516,837, the disclosure of which is incorporated by reference. Commonly used refrigeration lubricants such as Polyol Esters (POEs), Poly Alkylene Glycols (PAGs) and esterified Poly Alkylene Glycols that are used in refrigeration machinery with hydrofluorocarbon (HFC) refrigerants may be used with the refrigerant compositions of the present invention.

## **METHODS AND SYSTEMS**

The compositions of the present invention are useful in connection with numerous methods and systems, including as heat transfer fluids in methods and systems for transferring heat, such as refrigerants used in refrigeration, air conditioning and heat pump systems.

The preferred heat transfer methods generally comprise providing a composition of the present invention and causing heat to be transferred to or from the composition by changing the phase of the composition. For example, the present methods provide cooling by absorbing heat from a fluid or article, preferably  
5 by condensing a refrigerant comprising the present compositions and thereafter evaporating the refrigerant in the vicinity of the body or fluid to be cooled. In many of such processes, the step of compressing the refrigerant vapor, usually with a rotary compressor or similar equipment, is also included as part of the refrigeration cycle. Such a step is then sometimes followed by an intermediate cooling step to remove at  
10 least a portion of the heat added to the refrigerant composition of the present invention by the compression step. This intermediate cooling step is then preferably followed by a nominally isoenthalpic reduction of the pressure of the cooled, high pressure refrigerant vapor to cause at least a portion of the vapor to condense to a relatively cold liquid phase. In such embodiments, it is this reduced temperature  
15 refrigerant liquid which is then vaporized by heat transferred from the body or fluid to be cooled.

In another process embodiment of the invention, the compositions of the invention may be used in a method for producing heating which comprises  
20 condensing a refrigerant comprising the compositions in the vicinity of a liquid or body to be heated and thereafter evaporating the refrigerant. Such methods, as mentioned hereinbefore, frequently are reverse cycles to the refrigeration cycle described above.

According to one aspect of the present invention, a method for producing  
25 refrigeration is provided by condensing a fluoroalkene containing from 2 to 5 carbon atoms and at least 1 but no more than 2 double bonds and thereafter evaporating the fluoroalkene in the vicinity of a body to be cooled. Fluoroalkenes containing 3 carbon atoms and 1 double bond are preferred.

30 Because heat pump systems are simply the reverse of refrigeration systems, according to another aspect of the present invention, a method is provided for

producing heating by condensing a fluoroalkene containing from 2 to 5 carbon atoms and at least 1 but no more than 2 double bonds in the vicinity of a body to be heated and thereby evaporating the fluoroalkene. Again, fluoroalkenes containing 3 carbon atoms and 1 double bond are preferred.

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It has also been discovered that the fluoroalkenes of the present invention are miscible with existing polyalkylene glycol, polyalkylene glycol ester and polyol ester lubricating oils. Therefore, according to another aspect of the present invention, a liquid composition is provided for use in compression refrigeration, air-conditioning and heat pump systems in which a fluoroalkene containing from 2 to 5 carbon atoms and at least 1 but no more than 2 double bonds is combined with a sufficient amount to provide lubrication of an essentially miscible organic lubricant selected from polyalkylene glycol, polyalkylene glycol ester and polyol ester lubricants for compression refrigeration, air-conditioning and heat pump systems. In certain preferred embodiments, the lubricants of this invention are organic compounds which are comprised of carbon, hydrogen and oxygen with a ratio of oxygen to carbon sufficient to provide a degree of miscibility with the fluoroalkene such that when about 1 to 5 weight percent of the lubricant is added to the refrigerant fluid the mixture has one liquid phase. Preferably, the mixture has one liquid phase when 1 to 20 weight percent of the lubricant is present in the mixture. Most preferably, the mixture is one liquid phase in all proportions of the components of mixture. This solubility or miscibility preferably exists at at least one temperature from about -40°C and 70°C, and more preferably over essentially the entire temperature range.

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As used herein the term "refrigeration system" refers to any system or apparatus, or any part or portion of such a system or apparatus, which employs a refrigeration liquid or refrigerant to provide cooling. Such refrigeration systems include, for example, air-conditioners, electric refrigerators, chillers, transport refrigeration systems, commercial refrigeration systems, and the like.

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The present invention substitutes HFO's for HFC's, which, despite being safe for the ozone layer, are suspected of contributing to global warming. At least certain

of the preferred HFO's according to the present invention have physical characteristics that allow for their substitution for HFC's with only a minimum of equipment changes.

5           The polyalkylene glycol lubricants suitable for use with the present invention typically containing from about 5 to 50 oxylakylene repeating units that contain from 1 to 5 carbon atoms. The polyalkylene glycol can be straight chain or branched and can be a homopolymer or co-polymer of 2, 3 or more oxyethylene, oxypropylene, oxybutylene or oxypentylene groups or combinations thereof in any proportions.  
10 Preferred polyalkylene glycols contain at least 50% oxypropylene groups. Compositions according to the present invention may contain one or more polyalkylene glycols as the lubricant, one or more polyalkylene glycol esters as the lubricant, one or more polyol esters as the lubricant, or a mixture of one of more polyalkylene glycols, one or more polyalkylene glycol esters and one or more polyol  
15 esters. Vinyl ethers are also useful in this invention.

          Suitable polyalkylene glycols include the polyalkylene glycols of U.S. Patent No. 4, 971,712 and the polyalkylene glycol having hydroxy groups at each terminus disclosed by U.S. Patent No. 4,755,316. The disclosures of both patents are incor-  
20 porated herein by reference.

          While suitable polyalkylene glycols include glycols terminating at each end with a hydroxyl group, other suitable HFO lubricants include polyalkylene glycols in which either or both terminal hydroxyl group is capped. The hydroxyl group may be  
25 capped with alkyl groups containing from 1 to 10 carbon atoms, 1 to 10 carbon atom alkyl groups containing heteroatoms such as nitrogen, the fluoroalkyl groups described by U.S. Patent No. 4,975,212, the disclosure of which is incorporated herein by reference, and the like. When both polyalkylene glycol hydroxyl groups are end capped, the same type or a combination of two different types of terminal  
30 capping groups can be used.

Either or both hydroxyl groups can also be capped by forming the ester thereof with a carboxylic acid as disclosed by U.S. Patent No. 5,008,028, the disclosure of which is also incorporated herein by reference. The lubricating oils of this patent are referred to as polyol esters and polyalkylene glycol esters. The carboxylic acid can also be fluorinated. When both ends of the polyalkylene glycol are capped, either or both ends may be capped with an ester, or one end may be capped with an ester and the other not capped or capped with one of the aforementioned alkyl, heteroalkyl or fluoroalkyl groups.

Commercially available polyalkylene glycol lubricants include Goodwrench Refrigeration Oil for HFC-134a systems from General Motors and MOPAR-56 from Daimler-Chrysler, which is a polyalkylene glycol that is bis-capped by acetyl groups. Commercially available polyalkylene glycol esters include Mobil EAL 22 cc available from Exxon-Mobil and Solest 120 available from CPI Engineering Services, Inc. A wide variety of polyalkylene glycol lubricants are also available from Dow Chemical.

In preferred embodiments, the lubricants of this invention have viscosities of from about 1 to 1000 centistokes at about 37°C, more preferably in the range of from about 10 to about 200 centistokes at about 37°C and even more preferably of from about 30 to about 150 centistokes.

In addition to the HFO refrigerant and lubricant, compositions according to the present invention can include other additives or materials of the type used in refrigeration, air-conditioning and heat pump compositions to enhance their performance. For example, the compositions can also include extreme pressure and anti-wear additives, oxidation and thermal stability improvers, pour and floc point depressants, anti-foaming agents, other lubricants soluble in HFO's, and the like. Examples of such additives are disclosed in U.S. Patent No. 5,254,280, the disclosure of which is incorporated herein by reference. Compositions of the present invention can thus further include a quantity of mineral oil lubricant that would not otherwise be miscible or soluble with the HFO but is at least partially miscible or partially soluble when added to the HFO in combination with a polyalkylene glycol,

polyalkylene glycol ester or polyol ester. Typically, this is a quantity up to about 5-20 weight %. A surfactant may also be added to compatibilize the mineral oil with the polyalkylene glycol, polyalkylene glycol ester or polyol ester and the HFO, as disclosed in U.S. Patent No. 6,516,837, the disclosure of which is incorporated  
5 herein by reference.

Any of a wide range of methods for introducing the refrigeration compositions of the present invention to a compression refrigeration, air-conditioning or heat pump system can be used from the present invention. For example, one method  
10 comprises attaching a refrigerant container to the low-pressure side of a refrigeration system and turning on the refrigeration system compressor to pull the refrigeration composition into the system. In such embodiments, the refrigerant container may be placed on a scale such that the amount of refrigeration composition entering the system can be monitored. When a desired amount of refrigeration composition has  
15 been introduced into the system, charging is stopped. Alternatively, a wide range of charging tools, known to those skilled in the art, are commercially available. Accordingly, in light of the above disclosure, those of skill in the art will be readily able to introduce the HFO refrigerant and refrigeration compositions of the present invention into compression refrigeration, air-conditioning and heat pump systems  
20 without undue experimentation.

## EXAMPLES

The following examples are provided for the purpose of illustrating the present invention but without limiting the scope thereof.

### EXAMPLE 1

The coefficient of performance (COP) is a universally accepted measure of refrigerant performance, especially useful in representing the relative thermodynamic efficiency of a refrigerant in a specific heating or cooling cycle involving evaporation  
30 or condensation of the refrigerant. In refrigeration engineering, this term expresses the ratio of useful refrigeration to the energy applied by the compressor in compressing the vapor. The capacity of a refrigerant represents the volumetric

efficiency of the refrigerant and provides some measure of the capability of a compressor to pump quantities of heat for a given volumetric flow rate of refrigerant. In other words, given a specific compressor, a refrigerant with a higher capacity will deliver more cooling or heating power. One means for estimating COP of a refrigerant at specific operating conditions is from the thermodynamic properties of the refrigerant using standard refrigeration cycle analysis techniques (see for example, R.C. Downing, FLUOROCARBON REFRIGERANTS HANDBOOK, Chapter 3, Prentice-Hall, 1988).

A refrigeration/air conditioning cycle system is provided where the condenser temperature is about 150°F and the evaporator temperature is about -35°F under nominally isentropic compression with a compressor inlet temperature of about 50°F. COP is determined for several compositions of the present invention over a range of condenser and evaporator temperatures and reported in Table I below, based upon HFC-134a having a COP value of 1.00, a capacity value of 1.00 and a discharge temperature of 175 °F.

TABLE I

REFRIGERANT COMPOSTION	Relative COP	Relative CAPACITY	DISCHARGE TEMPERATURE
HFO 1225ye	1.02	0.76	158
HFO trans-1234ze	1.04	0.70	165
HFO cis-1234ze	1.13	0.36	155
HFO 1234yf	0.98	1.10	168

This example shows that certain of the preferred compounds for use with the present compositions each have a better energy efficiency than HFC-134a (1.02, 1.04 and 1.13 compared to 1.00) and the compressor using the present refrigerant compositions will produce discharge temperatures (158, 165 and 155 compared to 175), which is advantageous since such result will likely leading to reduced maintenance problems.



## EXAMPLE 2

The miscibility of HFO-1225ye and HFO-1234ze with various refrigeration lubricants is tested. The lubricants tested are mineral oil (C3), alkyl benzene (Zerol 150), ester oil (Mobil EAL 22 cc and Solest 120), polyalkylene glycol (PAG) oil (Goodwrench Refrigeration Oil for 134a systems), and a poly(alpha-olefin) oil (CP-6005-100). For each refrigerant/oil combination, three compositions are tested, namely 5, 20 and 50 weight percent of lubricant, with the balance of each being the compound of the present invention being tested

The lubricant compositions are placed in heavy-walled glass tubes. The tubes are evacuated, the refrigerant compound in accordance with the present invention is added, and the tubes are then sealed. The tubes are then put into an air bath environmental chamber, the temperature of which is varied from about -50°C to 70°C. At roughly 10°C intervals, visual observations of the tube contents are made for the existence of one or more liquid phases. In a case where more than one liquid phase is observed, the mixture is reported to be immiscible. In a case where there is only one liquid phase observed, the mixture is reported to be miscible. In those cases where two liquid phases were observed, but with one of the liquid phases occupying only a very small volume, the mixture is reported to be partially miscible.

The polyalkylene glycol and ester oil lubricants were judged to be miscible in all tested proportions over the entire temperature range, except that for the HFO-1225ye mixtures with polyalkylene glycol, the refrigerant mixture was found to be immiscible over the temperature range of -50°C to -30°C and to be partially miscible over from -20 to 50°C. At 50 weight percent concentration of the PAG in refrigerant and at 60°, the refrigerant/PAG mixture was miscible. At 70°C, it was miscible from 5 weight percent lubricant in refrigerant to 50 weight percent lubricant in refrigerant.

## EXAMPLE 3

The compatibility of the refrigerant compounds and compositions of the present invention with PAG lubricating oils while in contact with metals used in refrigeration and air conditioning systems is tested at 350° C, representing conditions

much more severe than are found in many refrigeration and air conditioning applications.

Aluminum, copper and steel coupons are added to heavy walled glass tubes.  
Two grams of oil are added to the tubes. The tubes are then evacuated and one gram of refrigerant is added. The tubes are put into an oven at 350°F for one week and visual observations are made. At the end of the exposure period, the tubes are removed.

This procedure was done for the following combinations of oil and the compound of the present invention:

- a) HFC-1234ze and GM Goodwrench PAG oil
- b) HFC1243zf and GM Goodwrench oil PAG oil
- c) HFC-1234ze and MOPAR-56 PAG oil
- d) HFC-1243zf and MOPAR-56 PAG oil
- e) HFC-1225 ye and MOPAR-56 PAG oil.

In all cases, there is minimal change in the appearance of the contents of the tube. This indicates that the refrigerant compounds and compositions of the present invention are stable in contact with aluminum, steel and copper found in refrigeration and air conditioning systems, and the types of lubricating oils that are likely to be included in such compositions or used with such compositions in these types of systems.

#### COMPARATIVE EXAMPLE

Aluminum, copper and steel coupons are added to a heavy walled glass tube with mineral oil and CFC-12 and heated for one week at 350°C, as in Example 3. At the end of the exposure period, the tube is removed and visual observations are made. The liquid contents are observed to turn black, indicating there is severe decomposition of the contents of the tube.

CFC-12 and mineral oil have heretofore been the combination of choice in many refrigerant systems and methods. Thus, the refrigerant compounds and compositions of the present invention possess significantly better stability with many commonly used lubricating oils than the widely-used prior art refrigerant-lubricating oil combination.

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